

Composite Resonances effects on EWPT and Higgs diphoton decay rate

A. E. Cárcamo Hernández, Claudio O. Dib and Alfonso R. Zerwekh

Universidad Técnica Federico Santa María and Centro Científico-Tecnológico de Valparaíso, Casilla 110-V, Valparaíso, Chile

Abstract

In scenarios of strongly coupled electroweak symmetry breaking, heavy composite particles of different spin and parity may arise and cause observable effects on signals that appear at loop levels. The recently observed process of Higgs to $\gamma\gamma$ at the LHC is one of such signals. We study the new constraints that are imposed on composite models from $H \rightarrow \gamma\gamma$, together with the existing constraints from the high precision electroweak tests. We use an effective chiral Lagrangian to describe the effective theory that contains the Standard Model spectrum and the extra composites below the electroweak scale. Considering the effective theory cutoff at $\Lambda = 4\pi v \sim 3$ TeV, consistency with the T and S parameters and the newly observed $H \rightarrow \gamma\gamma$ can be found for a rather restricted range of masses of vector and axial-vector composites from 1.5 TeV to 1.7 TeV and 1.8 TeV to 1.9 TeV, respectively, and only provided a non-standard kinetic mixing between the W^3 and B^0 fields is included.

Keywords: Composite Higgs Models, Composite spin-1 and spin-0 resonances, EWT, Diphoton decay rate.

1. Introduction

One of the possible signals of composite Higgs boson models is the deviation of the $h \rightarrow \gamma\gamma$ channel from the Standard Model (SM) prediction, as it is a loop process sensitive to heavier virtual states. For instance this signal was predicted in the context of Minimal Walking Technicolor [1]. Consequently the recent $h \rightarrow \gamma\gamma$ signal reported by ATLAS and CMS collaborations [2–5], which is very close to the SM prediction, implies an additional constraint on composite models. In this regard, it is important to explore the consequences of this new constraint on composite models, in conjunction with those previously known from electroweak precision measurements.

Given the recent evidence of the Higgs boson, a strongly interacting sector that is phenomenologically viable nowadays should include this scalar boson in its low energy spectrum, but it is also assumed that vector and axial-vector resonances should appear as well, in a way that the so called Weinberg sum rules [6] are satisfied [7–9].

Here we formulate this kind of scenario in a gen-

eral way, without referring to the details of the underlying strong dynamics, by using a low energy effective Lagrangian which incorporates vector and axial-vector resonances, as well as composite scalars. One of these scalars should be the observed Higgs and the others should be heavier as to avoid detection at the LHC. Our inclusion of the vector and axial resonances is based on a 4-site Hidden Local Symmetry, which requires three scalar sectors (link fields) responsible for the breaking of the hidden local symmetries. This setup naturally leads to a spectrum that contains three physical scalars.

The main reason to still consider strongly interacting mechanisms of electroweak symmetry breaking (EWSB) as alternatives to the Standard Model mechanism is the so called hierarchy problem that arises from the Higgs sector of the SM. This problem is indicative that, in a natural scenario, new physics should appear at scales not much higher than the EWSB scale (say, around a few TeV) in order to stabilize the Higgs mass at scales much lower than the Planck scale ($\sim 10^{19}$ GeV). An underlying strongly interacting dynamics without fundamental scalars, which becomes non-perturbative

somewhere above the EW scale, is a possible scenario that gives an answer to this problem. The strong dynamics causes the breakdown of the electroweak symmetry through the formation of condensates in the vacuum [10–14].

Many models of strong EWSB have been proposed which predict the existence of composite particles such as scalars [15–28], vectors [29–35], both scalars and vectors [37–52] and composite fermions [53, 54]. These predicted scalar and vector resonances play a very important role in preserving the unitarity of longitudinal gauge boson scattering up to the cutoff $\Lambda \simeq 4\pi v$ [55–60]. One should add that a composite scalar does not have the hierarchy problem since quantum corrections to its mass are cut off at the compositeness scale, which is assumed to be much lower than the Planck scale.

In this work we assume that Electroweak Symmetry Breaking is due to an underlying strongly interacting sector that possesses a global $SU(2)_L \times SU(2)_R$ symmetry, which breaks down to the subgroup $SU(2)_{L+R}$. The SM electroweak symmetry $SU(2)_L \times U(1)_Y$ is assumed to be embedded as a local part of the $SU(2)_L \times SU(2)_R$ symmetry, so the spontaneous breaking of the latter leads to EWSB. The strong dynamics responsible for EWSB in general gives rise to massive composite fields. We will assume that only spin-zero and spin-one composites are lighter than the cutoff $\Lambda \simeq 4\pi v$ so that they explicitly appear as fields in the effective chiral Lagrangian. Composite states of spin 2 and higher are assumed to be heavier than the cutoff, and so are disregarded in this work. Consequently, the spectrum below the cutoff will have vector and axial vector fields (V_μ^a and A_μ^a , respectively) belonging to the triplet representation of the $SU(2)_{L+R}$ custodial group, as well as two massive composite scalars (h and H) and one pseudoscalar (η), all singlets under that group. We will identify the lightest scalar, h , with the state of mass $m_h = 126$ GeV discovered at the LHC. Concerning the coupling to fermions, the spin-one fields V_μ^a and A_μ^a will couple to SM fermions only through their kinetic mixings with the SM Gauge bosons, and the spin zero fields h , H and η interact with the fermions only via (proto)-Yukawa couplings.

In this work, we build an effective chiral lagrangian to represent this generic scenario below the symmetry breaking cutoff and study its consistency with the current phenomenology. In particular we study the effects on the high precision results on S and T and the recent ATLAS and CMS results at the LHC on $h \rightarrow \gamma\gamma$, all of which are loop processes that are sensitive to heavy virtual particles.

2. The Model

We formulate our strongly coupled sector by means of an effective chiral Lagrangian that incorporates the heavy composite states by means of local hidden symmetries [68]. As shown in detail Ref. [47], this Lagrangian is based on the symmetry $G = SU(2)_L \times SU(2)_C \times SU(2)_D \times SU(2)_R$. The $SU(2)_C \times SU(2)_D$ part is a hidden local symmetry whose gauge bosons are linear combinations of the vector and axial-vector composites, and the SM gauge fields (see Ref. [47] for details). The SM gauge group, on the other hand, is contained as a local form of the $SU(2)_L \times SU(2)_R$ global symmetry of the underlying dynamics.

As the symmetry G is spontaneously broken down to the diagonal subgroup $SU(2)_{L+C+D+R}$, it is realized in a non-linear way with the inclusion of three link fields (spin-0 multiplets). These link fields contain two physical scalars h and H , one physical pseudoscalar η , the three would-be Goldstone bosons absorbed as longitudinal modes of the SM gauge fields and the six would-be Goldstone bosons absorbed by the composite triplets V_μ and A_μ . In the framework of strongly interacting dynamics for EWSB, the interactions below the EWSB scale among the SM particles and the extra composites can be described by the effective Lagrangian [47]:

$$\begin{aligned}
\mathcal{L} = & \frac{v^2}{4} \langle D_\mu U D^\mu U^\dagger \rangle - \frac{1}{2g^2} \langle W_{\mu\nu} W^{\mu\nu} \rangle \\
& - \frac{1}{2g'^2} \langle B_{\mu\nu} B^{\mu\nu} \rangle + \frac{c_{WB}}{4} \langle U^\dagger W_{\mu\nu} U B^{\mu\nu} \rangle \\
& + \sum_{R=V,A} \left[-\frac{1}{4} \langle R_{\mu\nu} R^{\mu\nu} \rangle + \frac{1}{2} M_R^2 R_\mu R^\mu \right] \\
& - \frac{f_V}{2\sqrt{2}} \langle V^{\mu\nu} (u W_{\mu\nu} u^\dagger + u^\dagger B_{\mu\nu} u) \rangle \\
& - \frac{ig_V}{2\sqrt{2}} \langle V^{\mu\nu} [u_\mu, u_\nu] \rangle + \frac{f_A}{2\sqrt{2}} \langle u_{\mu\nu} A^{\mu\nu} \rangle \\
& - \frac{if_A}{2\sqrt{2}} \langle (u W_{\mu\nu} u^\dagger + u^\dagger B_{\mu\nu} u) [A^\mu, u^\nu] \rangle \\
& - \frac{ik f_A}{2\sqrt{2}} \langle u_{\mu\nu} [V^\mu, u^\nu] \rangle + \alpha_\eta \langle V_\mu A^\mu \rangle \eta \\
& + \beta_\eta \langle V_\mu u^\mu \rangle \eta + \mathcal{L}' \\
& + \sum_{S=h,H,\eta} \left[\frac{1}{2} \partial_\mu S \partial^\mu S + \frac{m_S^2}{2} S^2 \right] \\
& + \sum_{S=h,H} [\alpha_S S \langle u_\mu u^\mu \rangle + \beta_S S \langle V_\mu V^\mu \rangle] \\
& + \sum_{S=h,H} [\gamma_S S \langle A_\mu A^\mu \rangle + \delta_S S \langle A_\mu u^\mu \rangle] \quad (1)
\end{aligned}$$

where \mathcal{L}' corresponds to the part of the Lagrangian which includes: the interactions of *two* of the heavy spin-one fields with the SM Goldstone bosons and gauge fields, the interactions involving *three* heavy spin-one fields, the quartic self-interactions of V_μ and of A_μ , the contact interactions involving the SM gauge fields and Goldstone bosons, the interaction terms that include two of the spin-zero fields coupled to the SM Goldstone bosons or gauge fields, or to the composite V_μ and A_μ fields, the mass terms for the SM quarks as well as interactions between the spin-0 fields h , H and η and the SM fermions. Besides that, the dimensionless couplings in Eq. (1) are given in Ref.[47], and the following definitions are fulfilled:

$$\begin{aligned} U(x) &= e^{i\hat{\pi}(x)/v}, & \hat{\pi}(x) &= \tau^a \pi^a, & u &\equiv \sqrt{U}, \\ B_\mu &= \frac{g'}{2} \tau^3 B_\mu^0, & W_\mu &= \frac{g}{2} \tau^a W_\mu^a, & R_\mu &= \frac{1}{\sqrt{2}} \tau^a R_\mu^a, \\ R &= V, A, & D_\mu U &= \partial_\mu U - iB_\mu U + iU W_\mu, \\ \hat{X}_{\mu\nu} &= \nabla_\mu X_\nu - \nabla_\nu X_\mu, & X &= R, u & u_\mu &= iu^\dagger D_\mu U u^\dagger, \\ \nabla_\mu R &= \partial_\mu R + [\Gamma_\mu, R], \\ \Gamma_\mu &= \frac{1}{2} [u^\dagger (\partial_\mu - iB_\mu) u + u (\partial_\mu - iW_\mu) u^\dagger]. \end{aligned} \quad (2)$$

Our effective theory is based on the following assumptions [47]:

1. The Lagrangian responsible for EWSB has an underlying strong dynamics with a global $SU(2)_L \times SU(2)_R$ symmetry which is spontaneously broken by the strong dynamics down to the $SU(2)_{L+R}$ custodial group. The SM electroweak gauge symmetry $SU(2)_L \times U(1)_Y$ is assumed to be embedded as a local part of the $SU(2)_L \times SU(2)_R$ symmetry. Thus the spontaneous breaking of $SU(2)_L \times SU(2)_R$ also leads to the breaking of the electroweak gauge symmetry down to $U(1)_{em}$.
2. The strong dynamics produces composite heavy vector fields V_μ^a and axial vector fields A_μ^a , triplets under the custodial $SU(2)_{L+R}$, as well as a composite scalar singlet h with mass $m_h = 126$ GeV, a heavier scalar singlet H , and a heavier pseudoscalar singlet η . These fields are assumed to be the only composites lighter than the symmetry breaking cutoff $\Lambda \simeq 4\pi v$.
3. The heavy fields V_μ^a and A_μ^a couple to SM fermions only through their kinetic mixings with the SM Gauge bosons.
4. The spin zero fields h , H and η interact with the fermions only via (proto)-Yukawa couplings.

3. Study of effects on T , S and $h \rightarrow \gamma\gamma$.

In the Standard Model, the $h \rightarrow \gamma\gamma$ decay is dominated by W loop diagrams which can interfere destruc-

tively with the subdominant top quark loop. In our strongly coupled model, the $h \rightarrow \gamma\gamma$ decay receives extra contributions from loops with charged V_μ and A_μ , as shown in Figure 1 [47]. Notice that we have not

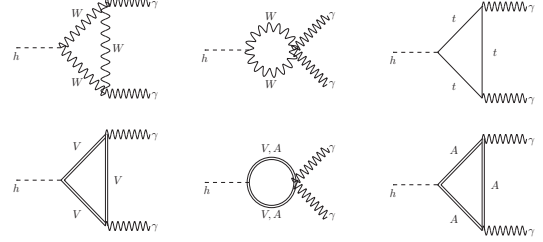


Figure 1: One loop Feynman diagrams in the Unitary Gauge contributing to the $h \rightarrow \gamma\gamma$ decay.

considered the contribution from contact interactions of gluons, such as

$$\mathcal{L}_{ggVV} = \frac{a_{ggVV}}{\Lambda^2} G_{\mu\nu} G^{\mu\nu} V_\alpha V^\alpha. \quad (3)$$

to the Higgs production mechanism at the LHC, $gg \rightarrow h$, which could have a sizable effect that might contradict the current experiments. Nevertheless, we have checked that this contribution is negligible provided the effective coupling $a_{ggVV} < 0.5$. We recall that the heavy vector and heavy axial-vector resonances are colorless, and therefore they do not have renormalizable interactions with gluons. In this work we want to determine the range of the heavy vector masses which is consistent with the events in the $h \rightarrow \gamma\gamma$ decay recently observed at the LHC. To this end, we will introduce the ratio $R_{\gamma\gamma}$, which measures the $\gamma\gamma$ signal produced in our model relative to the signal within the SM:

$$\begin{aligned} R_{\gamma\gamma} &= \frac{\sigma(pp \rightarrow h) \Gamma(h \rightarrow \gamma\gamma)}{\sigma(pp \rightarrow h)_{SM} \Gamma(h \rightarrow \gamma\gamma)_{SM}} \\ &\simeq a_{htt}^2 \frac{\Gamma(h \rightarrow \gamma\gamma)}{\Gamma(h \rightarrow \gamma\gamma)_{SM}}. \end{aligned} \quad (4)$$

where a_{htt} is the deviation of the Higgs-top quark coupling with respect to the SM.

Let us first study the masses of h , H and η up to one loop. The one-loop diagrams are shown in Fig. 2. Now, we want h to be the recently discovered Higgs boson of mass ~ 126 GeV, while H and η should be heavier, their masses satisfying the experimental bound $600 \text{ GeV} \lesssim m_H, m_\eta \lesssim 1 \text{ TeV}$. These masses have tree-level contributions directly from the scalar potential, but also

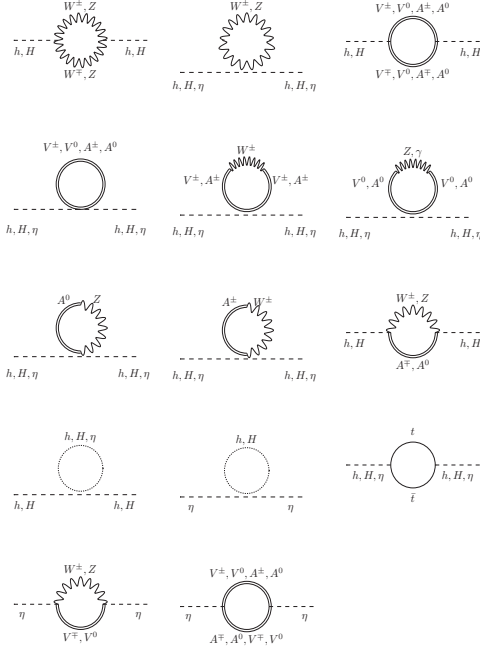


Figure 2: One loop Feynman diagrams in the Unitary Gauge contributing to the masses of the parity even h and H and parity odd η scalars [47].

important one-loop contributions from the Feynman diagrams shown in Fig. 2. All these one-loop diagrams have quadratic and some have also quartic sensitivity to the ultraviolet cutoff Λ of the effective theory. The calculation details are included in Ref. [47]. As shown there, the contact interaction diagrams involving V_μ and A_μ in the internal lines interfere destructively with those involving trilinear couplings between the heavy spin-0 and spin-1 bosons. As shown in Ref. [47], the quartic couplings of a pair of spin-1 fields with two h 's are equal to those with two H 's. This implies that contact interactions contribute at one-loop level equally to the h and H masses. On the other hand, since the couplings of two spin-1 fields with one h or one H are different, i.e., $a_{hWW} \neq a_{HWW}$, $a_{hAA} \neq a_{HAA}$, $a_{hWA} \neq a_{HWA}$, $a_{hZA} \neq a_{HZA}$, these loop contributions cause the masses m_h and m_H to be significantly different, the former being much smaller than the latter (notice that in the Standard Model, $a_{hWW} = b_{hWW} = 1$, implying an exact cancellation of the quartic divergences in the one-loop contributions to the Higgs mass). As it turns out, one can easily find conditions where the terms that are quartic in the cutoff cause partial cancelations in m_h , but not so in

m_H and m_η , making m_h much lighter than the cutoff Λ (e.g. $m_h \sim 126$ GeV) while m_H and m_η remain heavy. In Figs. 3.a and 3.b we show the sensitivity of the light scalar mass m_h to variations of M_V and a_{htt} , respectively. These Figures show that the values of M_V and a_{htt} have an important effect on m_h . We can see that these models with composite vectors and axial vectors have the potential to generate scalar masses well below the supposed value around the cutoff, but only in a rather restricted range of parameters. The high sensitivity to the parameters, however, does not exhibit a fine tuning in the usual sense: that deviations from the adjusted point would always bring the mass back to a “naturally high” value near the cutoff. Here, the adjustment of parameters could bring the light scalar mass either back up or further below the actual value of 126 GeV [47]. Let us now analyze the constraints imposed on the parameters by the values of T and S given by the experimental high precision tests of electroweak interactions. The Feynmann diagrams contributing to the T and S parameters are shown in Figures 3 and 4, respectively. As shown in Ref. [47], in general the expressions for T and S exhibit quartic, quadratic and logarithmic dependence on the cutoff $\Lambda \sim 3$ TeV. However, the contributions coming from loops containing the h , H and η scalars are not very sensitive with the cutoff, as they do not contain quartic terms in Λ . As a consequence, T and S happen to have a rather mild sensitivity to the masses of H and η , and so we will restrict our study to a scenario where H and η are degenerate in mass at a value of 1 TeV. In contrast, most of the other diagrams, i.e. those containing SM bosons and/or the composite spin-1 fields V_μ or A_μ , have quartic and quadratic dependence on the cutoff, and as a consequence they are very sensitive to the masses M_V and M_A [47].

We can separate the contributions to T and S as $T = T_{SM} + \Delta T$ and $S = S_{SM} + \Delta S$, where

$$T_{SM} = -\frac{3}{16\pi \cos^2 \theta_W} \ln \left(\frac{m_h^2}{m_W^2} \right), \quad S_{SM} = \frac{1}{12\pi} \ln \left(\frac{m_h^2}{m_W^2} \right) \quad (5)$$

are the contributions within the SM, while ΔT and ΔS contain all the contributions involving the extra particles.

The experimental results on T and S restrict ΔT and ΔS to lie inside a region in the $\Delta S - \Delta T$ plane. At the 95% confident level (CL), these regions are the ellipses shown in Figs. 5. We can now study the restrictions on a_{htt} , M_V and κ imposed by a mass $m_h = 125.5$ GeV for the light Higgs boson and the two-photon signal $0.78 \lesssim R_{\gamma\gamma} \lesssim 1.55$, which at the same time respect the previously described bounds imposed by the T and

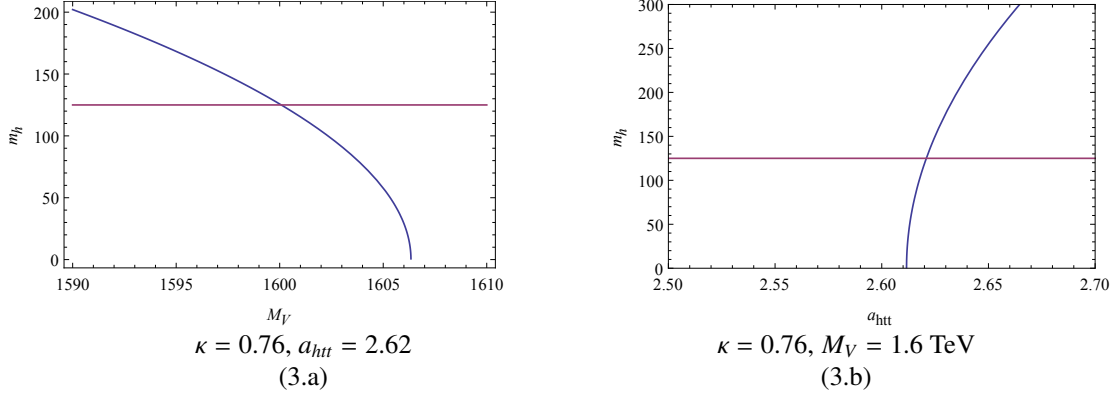
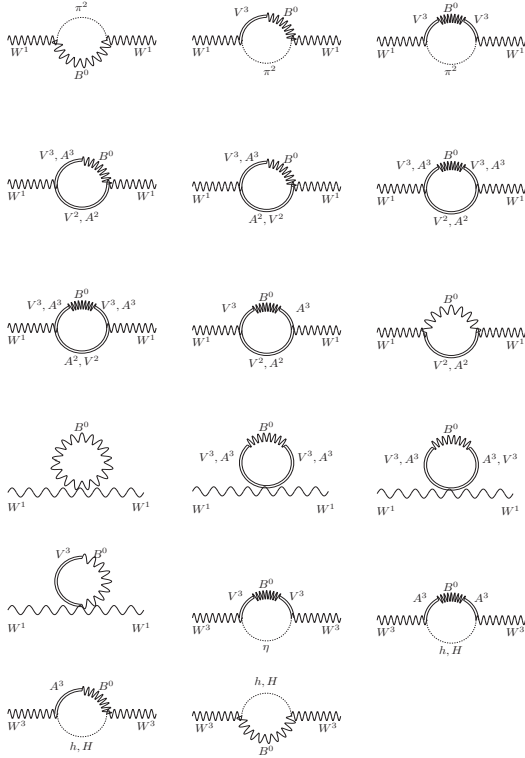


Figure 3: Light scalar mass m_h as function of M_V for $\kappa = 0.76$, $a_{htt} = 2.62$ TeV (Fig. 3.a), a_{htt} for $\kappa = 0.76$, $M_V = 1.6$ TeV (Fig. 3.b) [47]. The horizontal line corresponds to the value 126 GeV for the light Higgs boson mass.

S parameters at 95% CL. After scanning the parameter space we find that the heavy vector mass has to be in the range $1.51 \text{ TeV} \lesssim M_V \lesssim 1.75 \text{ TeV}$ in order for the T parameter to be consistent with the experimental data at 95% CL. Regarding the mass ratio $\kappa = M_V^2/M_A^2$ and the Higgs-top coupling a_{htt} , we find that they have to be in the ranges $0.75 \lesssim \kappa \lesssim 0.78$ and $2.53 \lesssim a_{htt} \lesssim 2.72$, respectively. Therefore, the light 126 GeV Higgs boson in this model couples strongly with the top quark, yet without spoiling the perturbative regime in the sense that the condition $\frac{a_{htt}^2}{4\pi} \lesssim 1$ is still fulfilled. Concerning the top coupling to the heavy pseudoscalar η , by imposing the experimental bound $600 \text{ GeV} \lesssim m_\eta \lesssim 1 \text{ TeV}$ for heavy spin-0 particles, we find that the coupling has the bound $a_{\eta tt} \lesssim 1.39$ for $M_V \simeq 1.51 \text{ TeV}$, $\kappa \simeq 0.75$ (lower bounds), and $a_{\eta tt} \lesssim 1.46$ for $M_V \simeq 1.75 \text{ TeV}$, $\kappa \simeq 0.78$ (upper bounds). Regarding the top coupling to the heavy scalar H , we find that it grows with m_H , and at the lower bound $m_H \sim 600 \text{ GeV}$ the coupling is restricted to be $a_{Htt} \simeq 3.53$, which implies that H also couples strongly to the top quark. Let us now study the restrictions imposed by the two-photon signal, given in terms of the ratio $R_{\gamma\gamma}$ of Eq. (4). We explored the parameter space of M_V and κ ($\kappa = M_V^2/M_A^2$) trying to find values for $R_{\gamma\gamma}$ within a range more or less consistent with the ATLAS and CMS results. In Fig. 6 we show $R_{\gamma\gamma}$ as a function of κ , for the fixed values $g_C v = 0.8 \text{ TeV}$ and $a_{htt} = 2.6$. We recall that $M_V = g_C v / \sqrt{1 - \kappa}$, being g_C the coupling constant of the strong sector. We chose $a_{htt} = 2.6$, which is near the center of the range $2.53 \lesssim a_{htt} \lesssim 2.72$ imposed by a light Higgs boson mass of $m_h = 125.5 \text{ GeV}$, as previously described. In turn, the value $g_C v$ was chosen in order to fulfill the condition $\frac{g_C^2}{4\pi} \lesssim 1$, which implies $g_C v \lesssim 0.9 \text{ TeV}$. In

any case, we checked that our prediction on $R_{\gamma\gamma}$ stays almost at the same value when the scale $g_C v$ is varied from 0.8 TeV to 1 TeV. Considering the bounds for κ shown in Fig. 6, together with the restriction imposed by T to be within its 95% CL, we found that M_A should have a value in a rather narrow range 1.78 TeV–1.9 TeV, while $M_V \lesssim 0.9 M_A$. To arrive at this conclusion, we selected three representative values of the axial vector mass M_A , namely at 1.78 TeV, 1.8 TeV and 1.9 TeV, and then compute the resulting T and S parameters. For each of these three cases, we found the corresponding values of M_V have to be in the ranges $1.54 \text{ TeV} \lesssim M_V \lesssim 1.57 \text{ TeV}$, $1.56 \text{ TeV} \lesssim M_V \lesssim 1.59 \text{ TeV}$ and $1.65 \text{ TeV} \lesssim M_V \lesssim 1.68 \text{ TeV}$ in order to have $R_{\gamma\gamma}$ within the range $0.78 \lesssim R_{\gamma\gamma} \lesssim 1.55$ and the light Higgs to have a mass $m_h = 125.5 \text{ GeV}$, without spoiling the condition $\frac{a_{htt}^2}{4\pi} \lesssim 1$.

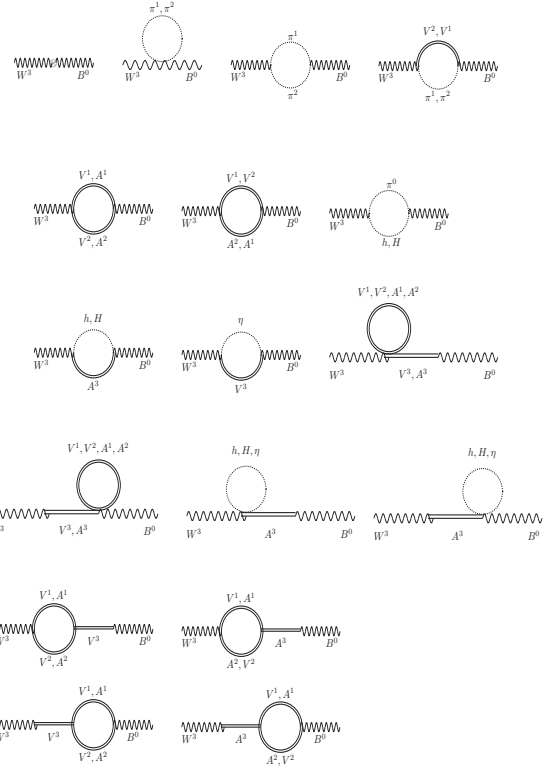
Now, continuing with the analysis of the constraints in the $\Delta T - \Delta S$ plane, we also find that, in order to fulfill the constraint on ΔS as well, an additional condition must be met: for the aforementioned range of values of M_V and M_A , the S parameter turns out to be unacceptably large, unless a modified $W^3 - B^0$ mixing is added. Here we introduce this mixing in terms of a coupling c_{WB} [see Eq. (1)]. As it is shown in Figs. 6, we find that the coupling c_{WB} must be in the ranges $0.228 \leq c_{WB} \leq 0.231$, $0.208 \leq c_{WB} \leq 0.212$ and $0.180 \leq c_{WB} \leq 0.182$ for the cases $M_A = 1.78 \text{ TeV}$, 1.8 TeV and 1.9 TeV, respectively. In Figs. 7.a, 7.b and 7.c we show the allowed regions for the ΔT and ΔS parameters, for three different sets of values of M_V and M_A . The ellipses denote the experimentally allowed region at 95% C.L., while the horizontal line shows the values of ΔT and ΔS in the model, as the mixing parameter c_{WB} is varied over the specified range in each case. As

Figure 4: One loop Feynman diagrams contributing to the T parameter [47].

shown, ΔT does not depend on c_{WB} (i.e. the line is horizontal), while ΔS does. Moreover, the ranges for c_{WB} clearly exclude the case $c_{WB} = 0$, as ΔS would fall outside the allowed region (the point would be further to the left of the corresponding ellipse).

4. Conclusions.

We considered a framework of electroweak symmetry breaking without fundamental scalars, based on an underlying dynamics that becomes strong at a scale which we assume $\Lambda \sim 3$ TeV. The spectrum of composite fields with masses below that scale is assumed to consist of spin-zero and spin-one fields, and the interactions among these particles and those of the Standard Model can be described by a $SU(2)_L \times SU(2)_R/SU(2)_{L+R}$ effective chiral Lagrangian. Specifically, the composite fields included here are two scalars, h and H , one pseudoscalar η , a vector triplet V_μ^a and an axial vector triplet A_μ^a . The lightest scalar, h , is taken to be the newly discovered state at the LHC, with mass

Figure 5: One loop Feynman diagrams contributing to the S parameter [47].

near 126 GeV. In this scenario, in general one must include a deviation of the Higgs-fermion coupling with respect to the SM, which is parametrized here in terms of a coupling we call a_{hff} . We found that our 126 GeV Higgs boson strongly couples with the top quark by a factor of about 2 larger than in the Standard Model. In addition we found that the $h \rightarrow \gamma\gamma$ rate to be consistent with the LHC observations provided the ratio between the composite vector and axial vector masses falls in a narrow range $M_V/M_A \sim 0.9$. We also found that the constraints on the T parameter at 95% C.L., together with the previously mentioned requirement of the $h \rightarrow \gamma\gamma$ decay rate, restrict the axial vector masses to be in the range $1.8 \text{ TeV} \lesssim M_A \lesssim 1.9 \text{ TeV}$. In addition, consistency with the experimental value on the S parameter requires the presence of a modified $W^3 - B^0$ mixing, which we parametrize in terms of a coupling c_{WB} . We also find that modified scalar-top quark and pseudoscalar top quark couplings may appear, in order to have in the scalar spectrum a light 125.5 GeV Higgs boson and heavy scalar H and heavy pseudoscalar η with

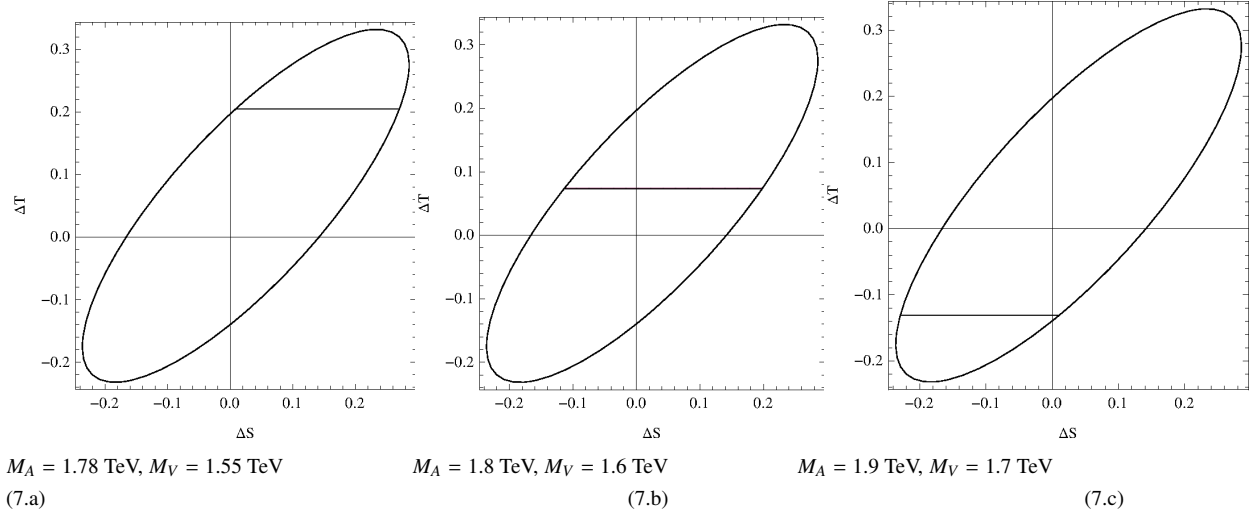


Figure 7: The $\Delta S - \Delta T$ plane in our model with composite scalars and vector fields [47]. The ellipses denote the experimentally allowed region at 95%CL taken from [81]. The origin $\Delta S = \Delta T = 0$ corresponds to the Standard Model value, with $m_h = 125.5$ GeV and $m_t = 176$ GeV. Figures a, b and c correspond to three different sets of values for the masses M_V and M_A , as indicated. The horizontal line shows the values of ΔS and ΔT in the model, as the mixing parameter c_{WB} varies over the ranges $0.228 \leq c_{WB} \leq 0.231$ (Fig. 7.a), $0.208 \leq c_{WB} \leq 0.212$ (Fig. 7.b), and $0.180 \leq c_{WB} \leq 0.182$ (Fig. 7.c).

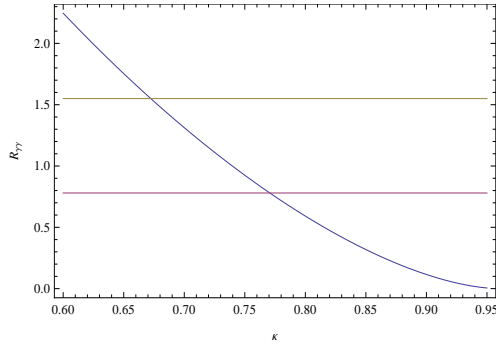


Figure 6: The ratio $R_{\gamma\gamma}$ as a function of κ for $g_{CV} = 0.8$ TeV. The horizontal lines are the $R_{\gamma\gamma}$ experimental values given by CMS and ATLAS, which are equal to 1.6 ± 0.4 and $1.8^{+0.460}_{-0.419}$, respectively [78, 79].

masses inside the experimental allowed range $600 \text{ GeV} \lesssim m_H, m_\eta \lesssim 1 \text{ TeV}$.

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